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FLAX CULTURE.

EXTRACTED FROM A REPORT OF

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., November 30, 1906.

SIR: I have the honor to transmit herewith and to recommend for publication as a Farmers' Bulletin the accompanying manuscript, entitled "Flax Culture." This paper has been extracted by Mr. William L. Marcy, of this Bureau, from an exhaustive report submitted by Prof. H. L. Bolley, of the North Dakota Agricultural Experiment Station, a collaborator of this Bureau, who was sent by the Department of Agriculture during the season of 1903 to investigate the conditions of flax culture in European countries, with a view to obtaining first-hand information to be placed at the disposal of flax growers in the United States. By agreement the complete report is being published by the North Dakota station as Bulletin No. 71 in the station series. The accompanying bulletin is designed to supersede Farmers' Bulletin No. 27, entitled "Flax for Seed and Fiber in the United States."

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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FLAX CULTURE.

CONDITIONS OF FLAX CULTURE IN THE UNITED STATES.

Flax culture in America from its introduction to the present time has been along primitive lines. The farm methods have been crude and the results have been very irregular, so that at the present time the crop has no permanent place in the agriculture of the country. Unlike other farm crops, though often very remunerative, it has never been permanently established in any particular farming community, nor have the farmers made any intelligent effort to retain it as a regular crop. In each new locality in which it has been introduced it has at first yielded bounteously of seed or fiber, according to type, with profit to the producer, but later gradually failed until the grower has actually met with loss; then the crop has been permanently abandoned. No effective effort seems to have been made to improve the strain or to get better seed or new varieties. It has been looked upon as a short-lived crop, suited only to new lands, and little, if any, attention has ever been given to improving the race or strain of seed at hand. Any seed which would germinate has been the criterion, and no grower has thought it of importance to grow his own seed. For one reason or another each community has given up the culture, quite satisfied that the crop is "exhausting" to the soil and unremunerative on old lands. Thus the crop has moved westward, from place to place and from State to State, so rapidly that it has been impossible to build up any permanent industry about it.

Original work at the North Dakota Agricultural Experiment Station during a number of years has fully established the fact that this firmly grounded general belief or prejudice of farmers against the flax crop is well founded. It has been ascertained, however, that the whole trouble is due to parasitism and not to soil exhaustion or to the accumulation of deleterious chemical substances in the soil. The details of these experiments and studies are recorded in various reports and bulletins of the North Dakota station. It is sufficient to state here that "flax-sick" soil is occasioned by the presence of a fungus, *Fusarium lini* Bolley, which may be introduced into new soil areas by means of the seed flax, and when once in the soil propagates with rapidity. Flax plants are destroyed by it at all ages of growth, from seed time to maturity. About four years' cropping to flax

suffices to destroy the usefulness of the soil for the growth of the crop if disease-bearing seed is used.

The flax crop has also been found to be subject to the attack of other destructive parasitic plants, but the fungus mentioned was found to be widespread in its distribution and sufficiently destructive to fully account for the disappearance of flax as a general crop in all but a few of the Northwestern States. The common practice of seed exchange and the further fact that no varieties of special merit have ever been generally recognized have in themselves been elements sufficiently potent to account for the general distribution of the dis-

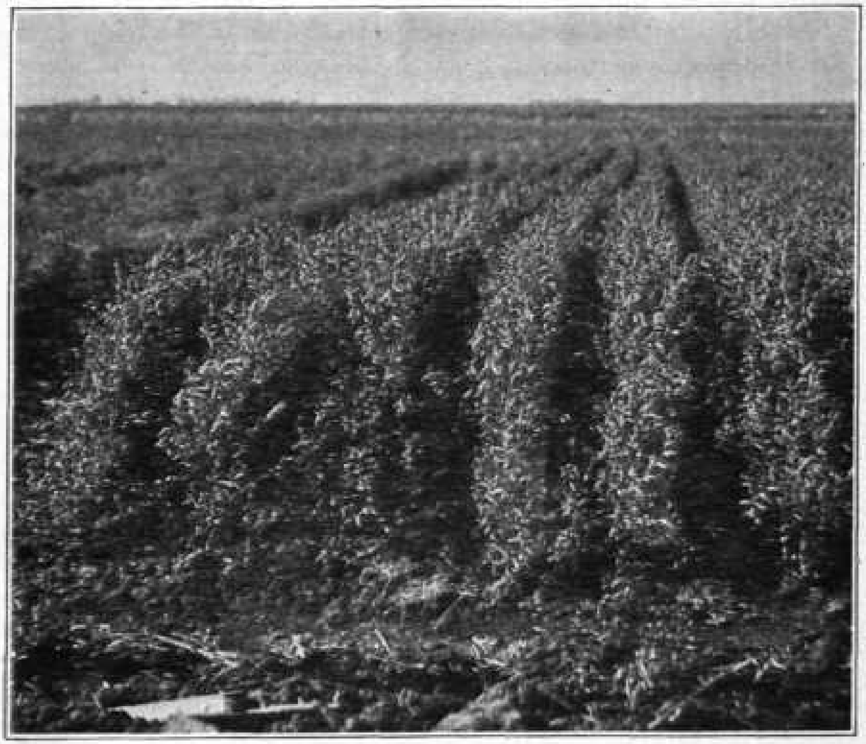

FIG. 1.—Crop of "immune" flax grown upon a rotation plat at the North Dakota Agricultural Experiment Station. This is the twelfth consecutive crop of flax and shows the possibilities of securing disease-resistant flax.

ease, even though it were not aided by wind, water, and other natural agencies.

The foregoing is a brief comment on the past and present of flax culture in America. The people seem to be awakening to a realization of the importance of flax culture and its associated industries. Enough has been done by a few persons to show that the crop may, with slight effort, be made to become of the greatest importance both to the farming public and to the commercial and manufacturing interests of the nation. (See fig. 1.)

IMPORTANCE AND VALUE OF THE CROP.

The importance of the flax crop need not be argued in detail with those who have had experience with it under conditions of successful growth, but the American farmer, once having dropped an unremunerative crop, does not take it up again except upon evident proof of worth. The flax crop is now making its last stand upon American soil unless intelligent agricultural methods restore it to a condition of regular productiveness throughout a large area. The practicability of doing this is the problem with which this bulletin has to deal, and the answer, looking to past history of the seed and fiber industry and to the present demand and sources of supply, may easily be in the affirmative. There is a large area of the Eastern and Central States in which the crop was once successfully grown, and the presence and use everywhere of products of less merit stand as a guarantee of a large future consumption of really meritorious flax products.

The acreage of the crop for seed production has been increased to such an extent in the newly-broken lands of the Northwest that the annual value of the seed crop of North Dakota alone is nearly or quite double that of all the States in which flax culture was carried on for any year previous to 1890. This statement alone suffices to show the great value of this crop if it could be fixed as a standard crop. The annual yield of seed in the State of North Dakota may be conservatively placed at 15,000,000 bushels. For the year 1905 it is placed at nearly 16,000,000 bushels.

During the season of 1904 the entire area in flax in the United States was approximately 3,200,000 acres, while in 1903 it approximated 3,700,000 acres. In 1903 the yield of seed was sufficient to produce approximately 70,000,000 gallons of linseed oil. The seed crop in areas new to cultivation has always been a paying one, though the remainder of the crop has been allowed to go to waste or has been burned. Millions of tons of straw have been burned each year, much of which, in quality and length for the production of fiber, far excels the average straw from which the Russian peasant makes the fiber which chiefly supplies the linen fabrics of the world.

There are now prospects of better things, and if the farmers of the country can hold the crop up to present productiveness, so that the industries now established about it—oil mills, tow mills, paper-pulp mills, binder-twine plants, crash toweling and bagging factories, etc.—need not cease operation, there is yet hope that the farmer may secure a large part of the value of the straw produced. Tow mills, with a capacity of 10 to 20 tons per day, are being operated at various points in the Northwest, and these pay for the ordinary straw from the thrashing machines from $2 to $3 per ton. Two large

binder-twine mills have recently been established in Minnesota and Michigan, where the flax straw, with the seed, is purchased and the fiber from the straw is made into binder twine, while the seed is cleaned for the oil mills. These mills utilize both straw and seed on a much larger scale than has ever been attempted heretofore in the United States, where the hand-labor methods of Europe seem to be impracticable. The farmers in these localities must see to it that all possible effort be made to keep up the productiveness in straw, as from or about these mills must come the first development of a real fiber industry. For the use of twine and cordage manufactories a type of straw similar to that shown in figure 11 (p. 35) would be very desirable.

DISTRIBUTION OF THE CROP.

Great Britain is not only the greatest user of flax fiber, but is also the greatest importer of flaxseed for oil purposes. It will, perhaps, be interesting to merchants and future producers of this seed crop to take note of the countries which produce the seed and those which are the greatest importers and crushers of this product. The four chief flax-producing regions of the world, named in the order of their importance, are the United States, Argentina, Russia, and British India. For a long time Russia has held the chief place in the production of flaxseed for oil purposes, but Argentina and the United States have rapidly forged to the front in the production of flaxseed through the opening up of virgin sod to this crop, and probably also through the introduction of a higher class of harvesting machinery.

As yet the United States is not a great exporter of flaxseed. Its important crushing mills, located at Buffalo, Minneapolis, New York, and Chicago, are able practically to take care of the seed crop. It is estimated that from 70 to 80 per cent of the oil seed which is crushed in the United States is taken care of by four great mills at the above-mentioned points. There were about 40 mills in operation in the United States during the fall of 1902, having a combined crushing capacity approximating 30,000,000 bushels. These were capable of producing from 60,000,000 to 70,000,000 gallons of oil. The oil product is mostly used in this country, but the important by-product known as oil cake is exported to the various stock-feeding countries of Europe, furnishing a valuable element of export trade.

CLIMATIC CONDITIONS.

The regions in which the flax crop has been successfully grown, either for fiber or for seed, cover a wide latitude, being within the tenth and sixty-fifth parallels of north latitude. New culture areas in southern latitudes also show the crop successfully grown under

similar climatic conditions. As at present cultivated in Europe, the limitations as to climate are rather sharply defined. These are probably matters of variety and strain which have become established because of unintelligent cultivation rather than because of any definite attempts which growers have made to obtain new and suited strains or varieties.

Temperature, rainfall, atmospheric humidity, and soil type directly govern plant distribution. Generally speaking, the flax crop may be said to grow best in the colder parts of the temperate region. From a general survey of the different general regions in which it is cultivated, as, for example, northwest Russia, the northwestern portion of the Netherlands, north and east Ireland, southern Argentina, and the northwestern United States, it can hardly be doubted that "common flax" is at present bred to fit cool growth conditions within moderate extremes as to heat and drought. As far as the growth of the seed crop is concerned, its region of culture may be stated to be similar to that of successful spring wheat cultivation, while the fiber crop is at present produced in regions of heavier rainfall and somewhat cooler and more cloudy skies than those in which spring wheat is usually grown with success. The crop may also be said to possess either general capabilities or varieties and strains which allow of the production of fair crops of seed flax at least to the southern limits of winter-wheat producing regions.

It is also found that the climatic conditions of Brussels, St. Petersburg, the coast of Oregon and Washington, eastern Michigan, and northern Wisconsin furnish about equal qualities of the better types of fiber flax. The only point of variation seems to be that the seed-producing areas of our northwestern plains reach a higher July and August mean temperature than most of the flaxseed-producing areas of Europe and Asia.

The rainfall of two districts may vary much as to amount, yet the results as to soil and atmospheric plant environment remain essentially similar. The less measurable features of sunshine, cloudiness, fogginess, general atmospheric humidity, etc., are matters which vitally affect plant growth, and these are especially noteworthy as affecting the flax crop. For the production of fine long fiber of even quality, the plant must have an even, rather slow development, with few, if any, sudden checks. The cloudy sky and cool humid air, with an even but not too great soil moisture throughout the period of growth, is a feature of all fiber districts.

A little well-directed experimental effort may easily lead to the attainment of more hardy and more productive varieties of flax for both fiber and seed purposes. It seems quite probable that the fiber strains are farthest away from the normal type of the plant, for the

reason that more intelligent attention has been given to that culture. With persistent care of the seed and selection, aiming toward a proper separation of the types and the securing of strains of each which are suited to the climatic conditions in which they are to be grown, there is every reason to believe that the range of successful culture can be greatly extended in this country; for, while, as already noted, the limits with reference to climatic conditions for particular strains seem to be well marked, there is perhaps no other cultivated plant which is successfully and economically grown over so wide a range.

SOIL CONDITIONS.

Observations and studies of the soil relations of the flax crop lead to the belief that the question of soil type and fertility, as affecting the successful culture of this crop, is one of far less importance than has usually been supposed. Nearly all writers on flax culture have thought it necessary to state that flax demands a very fertile soil. The writer's observations in America, the Netherlands, Belgium, Russia, and Austria do not confirm the belief of these writers. The lighter soils of Ward and Ramsey counties, North Dakota, equal or excel the most fertile soils of the Northwest in flaxseed production; and the light, sandy, very poor forest or scrub lands of some of the flax districts of Russia easily produce the finest types of fiber flax when the system of culture is at all intelligent. Indeed, in Russia the writer found the peasantry continuing the culture of flax upon soils naturally light and so impoverished from the long-continued, ruinous "three-crop" rotation that the growing of oats and rye was no longer a possible consideration. This was a surprising confirmation of previous conclusions drawn from work done at the North Dakota Agricultural Experiment Station. It has also been shown in this work that the flax plant is less radical in its draft upon the soil than wheat, corn, or oats.

Experiments conducted by the North Dakota station on large plats definitely illustrate that flax is not particularly hard on the soil. In the Red River Valley it has often been found that the soil is too fertile for the growth of a flax crop when atmospheric and soil moisture is normal. The farmers of the valley often put flax upon summer-fallowed lands, thinking that such lands are too strong for the wheat crop. Observations of this practice have shown that very often the flax crop almost fails and produces a poorer yield of seed because of this extra fertility. In droughty seasons the flax crop has shown itself able to stand on very fertile lands, but frequently it is almost worthless when anything more than an ordinary rainfall occurs. It has also been very clearly demonstrated at the North Dakota station that considerably better crops of wheat may be raised after flax than after wheat.

By comparing soil statistics, contrasting the chemical composition of farm crops, and considering extremely various types of soil upon which fine crops of flax fiber and flaxseed have been grown, it has been made evident that flax growing is not injurious to the soil. The chemical analyses of the soils of some of the noted Russian flax-producing districts bear out this statement. The lesson for American farmers is that, so far as flax is concerned, soil quality is rather a secondary consideration. The strains of seed used and the climatic and atmospheric conditions seem to be first in order of importance.

GROWTH PERIODS OF THE CROP.

The flax plant of cultivation is naturally an annual and is therefore limited to climatic and soil conditions which are suited to the growth of such plants. In certain southern regions, including southern France, it is sometimes cultivated as a winter annual, but such varieties are found to mature when sown as spring crops in the usual flax-growing regions. The complete growth period varies somewhat according to the types or varieties, and quite considerably according to the climate and region in which the crop is grown. Flax may, however, be looked upon as a short-season crop. It is quite common for the seed crop to be matured in from two and one-half to three months. This makes it a very important crop for northern regions. Indeed, the fiber crop, as has been previously noted, may be produced in very fine form in regions so far northward that few other crops may be successfully matured.

The entire growth periods of the plant may for convenience be divided into (1) the period immediately following seed germination and preceding the development of the regular foliage leaves, (2) the period from the seed-leaf stage to the blossoming stage, (3) the period of flowering and boll formation, and (4) the period of maturing. Very much depends upon the conditions of weather and soil during these definite periods of growth as to the final types of the products; and much depends also upon whether one is growing the crop for the production of fiber or seed, what sort of weather should be hoped for, and what soil conditions one should strive to maintain.

Generally speaking, a halting, irregular growth will result in the formation of a woody straw and a poor type of fiber product. There may or may not be a good seed crop produced under these conditions. If the aim is to produce a long even growth of fine fiber, everything possible should be done to obtain an even and rather slow growth. Arrangements should be made to provide that texture and drainage of the soil which will give as constant a water supply as possible. Anything which checks the growth of the straw during the period preceding boll formation is sure to result in an inferior

type of fiber. If a drought sets in at some time when the straw should be making its greatest strides in length and increase of diameter, there will be a formation of woody straw and a thickening and hardening of the fiber cells, and the straw becomes contracted, stunted, and brittle.

Where the crop is being grown for seed purposes, the matter of an even growth is almost of equal importance. It is extremely important to the seed crop that the atmospheric conditions should be sufficiently dry to cause the sturdy woody type of stem growth and a heavy production of foliage, for the reason that seed production demands a strong branching plant body with large leaf surfaces. In order that the boll formation may be numerous and perfect and the seeds may be well filled, large leaf surfaces expanded to the sun and air are a necessity, as these are the manufacturing source of the seed content. Too much moisture throughout the growth season results in weak and imperfect stems and poor boll and seed formation. If a severe drought should occur at or near the time of flowering or boll and seed formation, it will prevent the proper flow of sap and occasion the hardening and ripening of the straw, especially of the slender and thin stems upon which the bolls are formed, thus cutting off the proper supply of food materials from the seeds. Every effort should, therefore, be made to provide a type of soil which will maintain to the last a sufficient supply of moisture. The flax plant when supplied with a subsoil moisture will stand very severe conditions of atmospheric heat and drought.

A period of extreme importance in the growth of the crop is that which immediately follows seed germination. It is of the utmost importance that the germination should be rapid and that the soil should be in such condition as to allow the seedlings to come immediately above the surface. This accounts for the great care which should be exercised in the preparation of the soil for the seed bed, as described later.

CULTURAL METHODS.

The matter of formulating some systematic methods of flax culture which shall be recognized as of special merit is of first importance when considering the question of establishing the crop as a staple one in any particular region. In America there is a great difference of opinion as to what methods should best be pursued in preparing the seed bed, sowing the seed, and harvesting the product. Generally the crop is looked upon as a side issue and is cared for without much uniformity of effort and method. Even in the old flax-producing regions of Europe the writer found that definite knowledge as to the best methods of handling the soil and seed is hardly to be had except from observation. A great diversity of belief was found to exist. The

processes generally followed and the methods which may be calculated to give the most satisfactory results are outlined in the following pages.

THE SEED.

The most successful flax growers place great stress upon the care with which the seed is handled and upon the type and character of seed which is used; but it is a peculiar, indeed, a strange feature of the entire system of flax culture that no matter what region is visited one finds that the producer of the crop believes he should send to some distant region to procure seed. It is evident that this belief alone would result in a very thorough mixing of all the kinds, types, or varieties, and at the same time it practically eliminates the idea of seed development or seed breeding.

The writer is convinced that the raising of properly-cared-for home-grown seed would be of great advantage to the entire fiber industry of the Netherlands. This statement is made here in order to impress upon the American flax producer the fact that, if it is hoped ever to make the crop reach a standard of excellence, he must cease to buy seed of unknown quality and must proceed to grow the crop from seed of known pedigree. Experiments with farm crops have for a number of years shown that crops in their climatic environment do not degenerate by being grown for a long time upon the same type of soil. The cause of weakening depends upon other features which are not properly considered. The Dutch grower persists in sowing the seed thick upon the ground in order to give the fine type of fiber straw. He also pulls the straw while yet somewhat immature, that he may procure what he considers the best grade of fiber. The result is that each year the seed becomes weaker and weaker. Those who are in the business of growing fiber flax can well afford to set aside a piece of ground in order to produce a sufficient quantity of thoroughly matured seed of a pure type with which to seed their lands.

The quantity of seed sown to to the acre throughout each particular flax-growing region is fairly uniform. The Russian growers who sow the crop for oil production approximate very closely one-half bushel of good seed per acre. The Dutch, Belgian, and Russian growers of fiber flax sow very uniformly 8 to 10 pecks of seed per acre, according to the strength of the land and the moisture conditions which the crop can stand. The Russian seed costs Hollanders approximately from $2.50 to $4 per acre, because before sowing great care is taken to grade out everything but the very plumpest and best seeds. The effect of thickness of seeding upon the fineness of the fiber is shown in figure 2.

Because of its capability of absorbing water and of its oil content, flaxseed is of such a nature as readily to lose its viability. It is

particularly susceptible to injury by heating in the bin, by exposure to high dry-storage temperatures, or by exposure to slight amounts

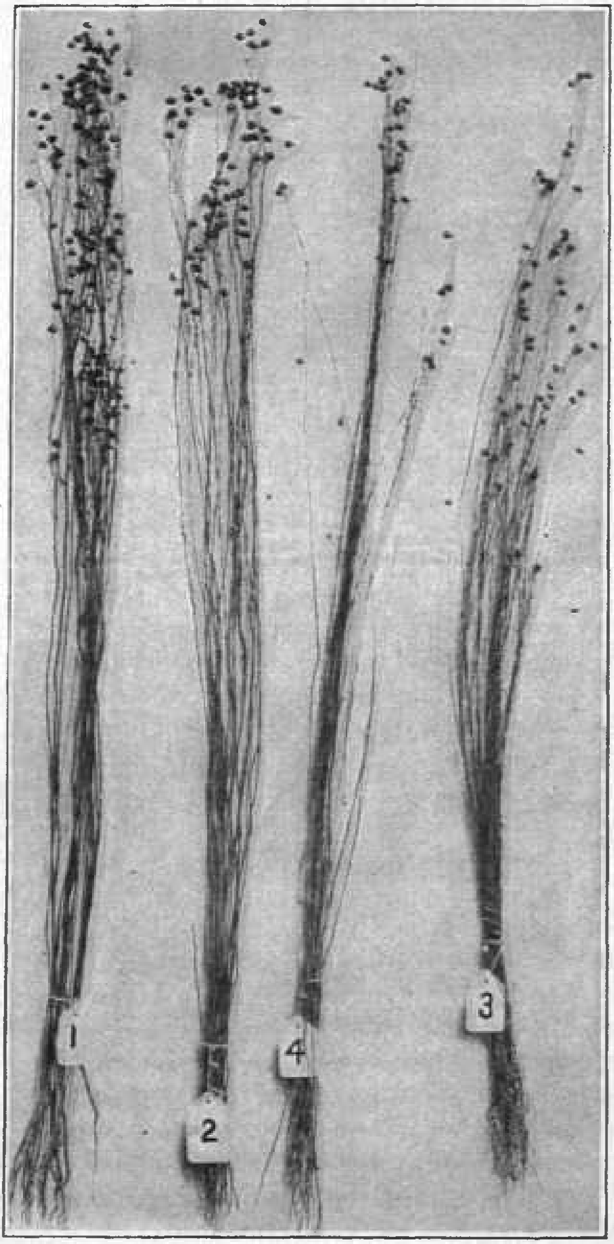

FIG. 2.—North Dakota grown fiber straw from seed sown at the rate of (1) 1 bushel, (2) 1¼ bushels, (3) 2½ bushels, and (4) 1½ bushels per acre, showing that fineness of fiber depends largely upon thickness of seeding.

of moisture under conditions of low temperature. As the young plants are very susceptible to the action of molds and other fungi

which attack the seedlings and the mother seeds at the time of germination, it is of great importance that the seed should be stored dry, so that the spores of such fungi can not gain a hold upon the seed. Flaxseed for sowing purposes should therefore be harvested dry and stored in a cool dry place.

THE LAND.

In America flax growers make little distinction as to what type of soil they select on which to grow the crop. Speaking generally, the farmers of the Netherlands, Belgium, Germany, and Russia follow the same course. The writer's observations show that the kinds of soil upon which the crop reaches the standard of perfection are very uniform in all regions, though fair crops may be raised upon soils of a great diversity of types.

For the fiber crop the texture of the upper layers of soil should be such as to give a finely compact surface, well drained, but of sufficiently sandy and loamy nature to allow the first growths of the root system of the young plant to be rapid, and yet it should not be so loose as to cause rapid drying or so compact as to cause baking and cracking. A feature of the greatest importance is that there should be a heavy, rather compact subsoil capable of persistent retention of moisture. The best types of the fiber crop of the Netherlands and of Russia were found upon soils which seemed to possess these general characteristics with a fine admixture of sea sand, giving a type of surface which could stand a large amount of water without baking and cracking during periods of partial drought.

As previously indicated, the matter of fertility seems to be of minor importance. The flax crop can be grown upon a soil so poor in the chemical elements needed for plant nutrition that scarcely any other crop could succeed, provided the other and more important conditions are favorable. In hot dry regions, where the crop is more commonly grown for seed, the features of the soil which are of extreme importance are those which insure a shallow but compact seed bed, a rapid first growth, and a steady water supply from a heavy underlying subsoil. While good crops of seed flax may be grown upon light lands with a gravel subsoil, this can only be expected in years when the season of boll formation has an abundant rainfall or receives its equivalent by irrigation.

As to the application of manures and fertilizers, the growers in the Netherlands do not recommend barnyard manure upon lands which are to be used for the production of fiber flax. They claim that this fertilizer produces too much wood in the straw and thickens the fiber. Many of the growers, who have to deal with lands of light quality that need pushing, apply a light top-dressing of saltpeter at about the blossoming period. This is said to lengthen the growth period and to soften and lengthen the straw.

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The matter of soil fertility and the use of fertilizers is one which must be worked out for each individual district and in many cases for each particular farm. The application of properly composted barnyard manures to the crop which is being grown for seed purposes can not be condemned, as the strong woody stem in this case is of material benefit in seed production. North Dakotans have found that the application of barnyard manure to this crop in the presence of the flax wilt is extremely harmful, the land being entirely ruined for flax in some cases by one application. After investigating the matter, the writer has come to the conclusion that this, in all cases, may be traced to the fact that diseased flax straw had been used for feeding the cattle, bedding them down, etc. Flax-disease fungi were thus able to permeate all of the resulting manure. Thorough composting of such manures has been found to be a preventive of this difficulty.

As flax is at present grown the importance of selecting new or previously unused land seems to be almost imperative. It is probable that this feature of flax culture can only be escaped by a judicious system of crop rotation, soil resting, and seed treatment, not because the soil is exhausted for flax, but because of the disease. Until a wise system of rotation or soil rest can be introduced, the farmer who expects success ought not to undertake the production of a flax crop on other than practically virgin soil. He must also practice careful selection, grading, and treatment of the seed if he wishes to continue successful production for any extended period.

THE SEED BED.

Great stress is usually placed by English writers on flax culture upon the idea of deep-working the soil in preparing the seed bed. The writer's work has shown that this idea is correct where compactness of soil is provided; but those who contend for a loosening and softening of the seed bed seem to be wholly in the wrong. The one thing that the flax crop can not stand is a friable, loose-textured soil. The best flax soils are found to be those with an admixture of very fine sea sand or silt resting upon a heavy compact subsoil. Where the better crops of Belgium, the Netherlands, and northwest Russia are seen growing, the topsoil, with its fine admixture of sand, soon after preparation becomes very compact, save only a slight blanket of surface sand which, worked to the top by means of rain, acts as a mulch or blanket to prevent cracking and baking in periods of slight drought.

The character of the soil naturally determines the time for working and plowing, but usually fall plowing is apt to give the best results in all those types of soil which tend to become more compact by working. In all cases in which the soils after deep plowing become more thoroughly compact by harrowing or top-working, much harrowing is

desirable. In very rich, loamy soils, which are liable to become loose and friable by persistent working—such, for example, as the lands of the Red River Valley—the top-working should be confined to the destruction of weeds and should be stopped at the slightest sign that overwork is tending to looseness, liability to blow, etc.

The aim is to provide a well-worked undersoil so as to give it a close texture and continuity for the ascent of water and at the same time to provide such surface working as to give a fine, shallow seed bed. Regardless of traditional theories, observations show that a compact soil underlying a shallow seed bed of not to exceed 1 inch in depth always gives the best results. The deep plowing and working should precede the seeding time just as long as possible, as its value consists in a proper aeration of the underlying soil for the preparation of food materials for the coming crop.

SEEDING TIME.

The seeding time for the fiber crop is always essentially the same in all regions. The seed is sown as soon in the spring as the work can be accomplished and not have the young plants injured by frost. The date varies according to the latitude and climatic features. The rather cool rapid-growth months of spring and early summer tend to produce long and fine types of fiber. The fiber plant can not withstand the hardening influence of the high dry heat of the late summer months.

In the case of the seed crop the same features will be found to hold true in regions having a long dry summer season. Northward and northwestward in America, including the Dakotas and Minnesota, the crop may be sown with hope of success even until the 10th or 20th of June, as the crop often takes on a very heavy growth in the cool autumn days. In North Dakota, if the late crop is not caught by early frosts, the yield is apt to be even greater than that from the early sown crop, which at times may be compelled to ripen too rapidly by the action of heat in August. The early crop also seems to be more often injured by rust. However, the date of seeding in North Dakota can not be much earlier than May 20 or later than June 20 without loss from frost.

SEEDING METHODS.

The methods of seeding for flax are as various as the people who grow the crop. The larger areas of the Netherlands and Belgium are seeded with ordinary grain drills, and such machinery is also used upon the largest estates in Russia where the crop is grown for oil production. Small areas in all countries are seeded by hand broadcast and harrowed in. Many fiber growers contend that this method gives best results. Russian peasants broadcast by hand almost exclusively.

If evenly cast it is supposed that all straws are shaded alike, and therefore mature evenly as to fiber.

The chief merits of any method of seeding must depend upon three points: The seed should be embedded at an even depth, not too deeply, and should be evenly distributed. The brush harrow, as commonly made by American farmers, gives good results when properly handled, but no scheme of broadcast seeding can give the regularity of depth that yields best results with this crop.

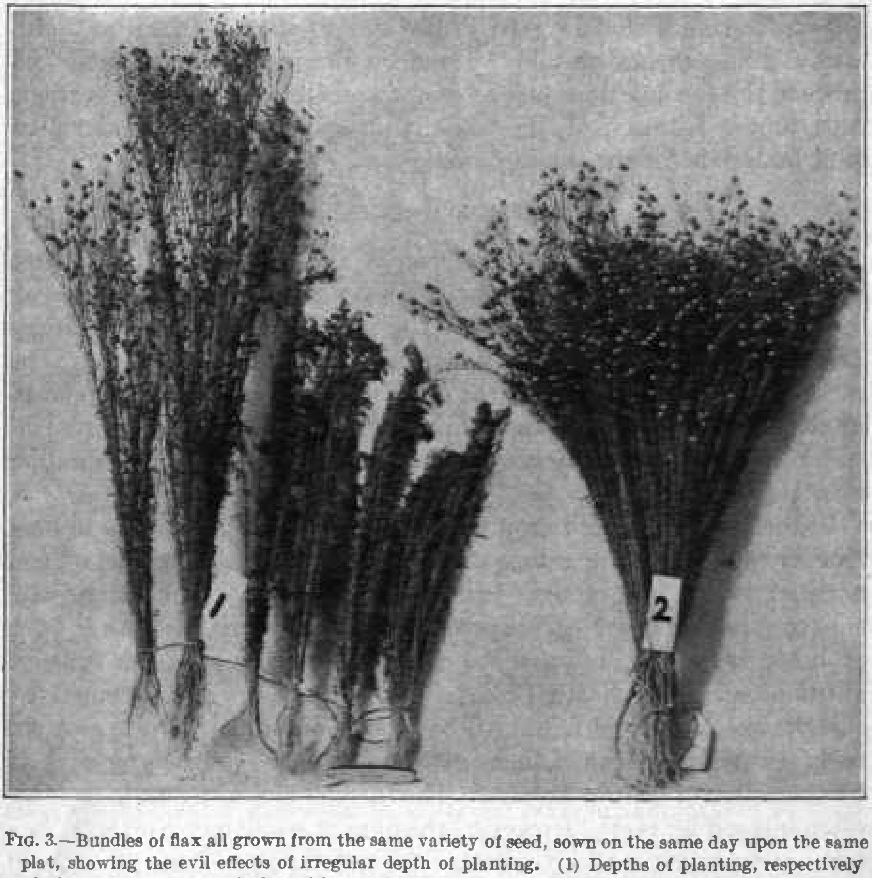

Fig. 3.—Bundles of flax all grown from the same variety of seed, sown on the same day upon the same plat, showing the evil effects of irregular depth of planting. (1) Depths of planting, respectively ½ inch, 1 inch, 1½ inches, 2 inches, 2½ inches, 3 inches; (2) crop planted evenly at one inch depth.

Considering entire crops, the best ones are quite the most apt to follow the drill. Regularity of depth in seeding is of the utmost importance with flax, whether planted for oil or for fiber purposes. If the seeds are buried at different depths there is very great irregularity of first growth, resulting in unequal maturing. (See fig. 3.) Trials at the North Dakota Agricultural Experiment Station have demonstrated that a matter of difference in depth of planting may cause differences of several weeks in ripening the seed crop. Where this difference in depth of planting occurs in a field it is evident

that a crop of evenly matured seed can not be harvested. There will be at harvest time plants in blossom and others which are losing seed by shelling, etc. This is a common fault in the large seed fields of North Dakota and can only be overcome by the careful preparation of the seed bed and careful use of the drill. More of the crop is lost in the Red River Valley region through too deep drilling upon too mellow soil than through any other cause. The young plants often are compelled to waste all of the energy stored in the seeds before they expand any leaf surfaces to the sunlight and thus become able to gain strength. With the fiber crop evenness of growth and maturing of the straw is of first importance.

CROP ROTATION.

With the flax grower, crop rotation is of great practical importance. He must either rotate or cease to grow the crop. This is the view of the writer, based on observation and experiment, and it is the verdict of all experienced growers. There seems to be but one alternative—breeding and selection. Crop rotation is the natural remedy for many troubles which come from too constant growth of one crop upon a given type of soil. Work at the North Dakota Experiment Station has pointed out that the chief reason flax fails so certainly after a few crops lies in the action of a fungous disease, but this is no argument against crop rotation, nor is it proof that the continuous culture of one crop is not a ruinous policy. While flax is not a gross feeder like other plants—and it can be proved that it does not feed more heavily upon the available plant foods than wheat, oats, or other cereals—yet it is probable that it has its own particular ways of depleting the soil and that a rest period, regardless of the disease problem, can not fail to be beneficial to the crop.

An effort to learn the best possible system of rotation for flax resulted in showing that among growers there is much confusion of ideas. Only one fact was characteristic of all replies obtained, viz, that there should be as long a period of years intervening between flax crops as possible. Most growers in the Netherlands and Belgium hold that the chief necessity for long series of crops in the rotations is due to the destructive action of flax wilt, but they also believe in the process as one that is essential to general agriculture. Of the best producers of fiber flax, few believe in less than seven-year series. Many recommend much longer rotation periods and favor the introduction of grass and pasture in the series of crops. A very common rotation in the Netherlands is as follows: (1) Manure or rape; (2) wheat; (3) rye; (4) legumes (horse beans); (5) flax; (6) potatoes; (7) potatoes; and (8) fallow—rest, and crop of weeds turned under as a green manure late in the season. If the soil is very fertile, the potatoes follow the legumes, preceding the flax.

In Russia the peasants, according to the compulsory customs of the particular commune, practice either three or six year rotations. In the better flax-producing villages the rule is usually for a six-year rotation, as follows: (1 and 2) Wheat; (3) oats; (4) rye; (5) pasture; (6) flax. In many districts the common rotation is (1) fallow; (2) wheat, rye, oats, or barley; (3) pasture for the village cattle; and then flax year after year until the soil is practically robbed of the strength necessary to support even grass.

In the northern regions of Russia, a scrub and timber country where the population is sparse, great crops of fiber flax are grown by the "land rest" method. After each flax crop the peasants allow the land to run wild as a village pasture and to grow up to scrub timber for ten or fifteen years. The scrub is then burned off and the breaking is cropped to flax. By this wasteful method they grow undoubtedly the best fiber straw known. The land cleared in this way seems to have all the advantages of virgin soil.

The feature most widely observed is that on light soils a leguminous crop is of much benefit in preparing the soil for flax culture. If, however, the soil naturally possesses much available nitrogen, the flax is sown as long after the leguminous crop as possible and is usually preceded by grass or hay crops. The most common procedure in all countries seems to be the placing of flax in the series after several years of grass and pasture. This seems important when freedom from the destructive action of wilt is considered. During the writer's investigations, however, no grower was found who believed that any sort of rotation series could serve as a complete specific against the occurrence of flax-sick soil. It is also self-evident that no rotation can be given which will fit all soils and regions. Experiments at the North Dakota Experiment Station seem to point to the marked value of one or more crops of cultivated corn in the series with the flax crop, preceded by hay and pasture sod of several years' standing.

CONTROL OF WEEDS.

Very little need be said of weeds. It is not supposed that they should be allowed in any carefully grown crop; yet there is probably no crop in which their presence is more pernicious than in flax culture. In the case of the fiber crop they must all be removed from the straw by hand before retting, a very costly process. Their presence in the crop also causes unevenness of growth and maturing, with the associated evils. In the seed crop they occasion by their extra foliage great difficulty in properly drying and curing the seed bolls for thrashing. The greatest difficulty is also experienced in attempting to grade weed seed from flaxseed; and whether the seed is being purchased for oil or for sowing purposes, there must be a loss to the

grower on account of the low price obtainable for such inferior seed. As the Russian peasant, even though he pulls the crop by hand, always puts into the seed he sells all of the weed seeds available, and as the seed exported by Russian seed houses is made up of many separate small collections of flaxseed from many different districts, one is apt to find many types of very bad weeds in any importation. Among the destructive weeds sure to be represented in such seed are flax dodder (*Cuscuta epilinum*), cornflower (*Centaurea cyanus*), and many types of mustard, including false flax (*Camelina sativa*) and various species of Roripia.

HARVESTING THE SEED.

Whether the seed is to be used for sowing purposes or for oil, great care is necessary in the harvesting process in order to hold the quality of the seed. The essentials are that the seed should be allowed to mature, be harvested dry, and be kept in a dry condition. Since there are no growers who practice growing fiber flax for seed purposes, it is easy to account for the fact that even the best which is to be had is of very uneven grade. In Russia the seed is sown so thick that only two or three of the topmost bolls are able to mature. When the crop is pulled the other bolls furnish weak, half-mature, scaly seeds. No Russian peasant grows any great quantity of seed, and before it reaches a seedsman many different lots are mingled.

FIBER PROCESSES.

Though of much interest and importance, it is not possible in this bulletin to discuss in full the fiber processes, but it is hoped that from the brief description which follows it will be seen that the taking up of the flax-fiber industry in America is not impossible of good results. Much has been said by writers of the "expert skill" of the workmen engaged in the fiber industries of the Netherlands and Russia, but the Russian labor was found by the writer to be of a cheap grade. In Belgium long experience in the retting process, as there practiced, has developed much skill, but no process involves the possession of superior mental ability on the part of the laborers or of knowledge which can not be quickly acquired by educated labor. As yet hardly any of the processes of flax-fiber preparation have passed beyond the stage of hand labor. When machinery is used it is of the simplest construction and operation and usually involves much hand work. The general steps of fiber preparation are briefly described under the separate topics which follow.

PULLING.

Everywhere the pulling of the straw is done by hand. The arguments for this practice are always essentially the same, viz, (1) that there is no machine which will do the work well, and (2) that it is wise to pull by hand, as all weeds may be discarded and the crop may be sorted and thrown into proper grades of straw. Some writers claim that there is much loss of fiber if one attempts to cut the crop, for the reason that "the best fiber is located in the lower stem and root." There is little or no foundation for this belief. The last 2 or 3 inches of stem is exceedingly woody and contains but little fiber and the root contains no fiber of value. At some of the large scutching mills in Belgium it was contended that the fiber from cut straw is unsatisfactory for spinning purposes, for the reason that fibers with cut ends do not bind together in the thread properly, that they slip, etc. There may be some basis for this belief, but it seems very doubtful that it can be a feature of any great importance. The principal reasons for pulling instead of cutting flax seem to be (1) to avoid stain and injury, which would result from soil moisture soaking into the cut stems while curing in the shock; (2) to secure better curing of the straw and ripening of the seed; (3) to secure straw of full length. Pulled flax commands a price of from $1 to $2 per ton more than cut flax.

Clean culture would eliminate the weeds, and the seed bed which is best suited to flax culture is of so even and smooth a nature when properly prepared that reaping machines could be set to run so close to the earth as to remove practically every inch of valuable straw. There is no successful pulling machine now in use, though its invention has been attempted. The crop as now grown in the Red River Valley could be cut and bound in bundles so as to lose less than 2 inches of valuable straw, and if special effort were made to prepare the soil even less loss would result. The cost of hand pulling by American labor would probably be so great as to make competition with foreign labor in the production of fiber impracticable, although it is surprising how rapidly the crop can be pulled by hand. The fact is not that it is particularly slow or hard work, but American laborers do not like to engage in types of labor which they think ought to be done by machinery, even if there is no machine suitable for the work.

THRASHING, OR SEED REMOVAL.

In European fiber work the seed is always removed by hand, or such simple machinery is used that hand labor is the main element. The attempt is to save the fiber in the small branches upon which the bolls are located. Much care is given to the proper drying of the straw and seed bolls or capsules, so that the work of seed removal

may be as easily effected as possible. The crop is sometimes left in small bundles or swaths as pulled, and then dried and stacked. Sometimes it is kiln-dried, or often in peasant districts hung in bunches upon fences or on racks put up for that purpose. (See fig. 4.)

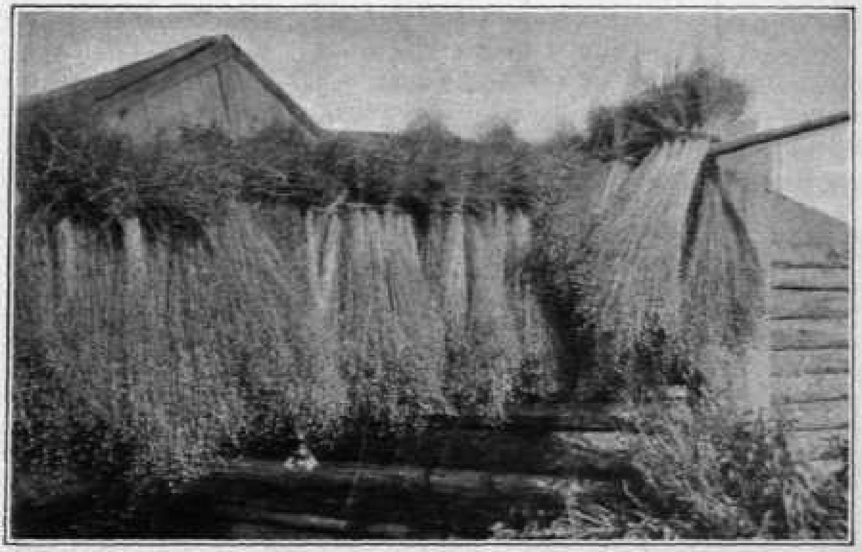

FIG. 4.—Common method used in Russia for drying the flax straw before removing the seed.

European growers of fiber flax contend that the proper saving of the seed crop should give sufficient seed to pay for all of the farming processes—indeed, all of the steps in the culture of the crop up to and including the process of retting.

RETTING.

The process of freeing the fiber from the woody and gummy substances, so that it can be easily removed by the processes of breaking and scutching, is known as retting. The work may be done either by chemical means or by the slower process of fermentation or rotting. The retting may be done in water or by a weathering process through exposure to dew, rain, and sun. The latter method is also one essentially of fermentation. The great mass of flax fiber of the world is produced by the natural fermentation method. Up to the present, chemical methods have been found too costly and the quality of fiber produced has not been satisfactory. Some very pretty types of fiber have at times been freed by chemical means, but large plants for such work are not as yet successful. The various chemical methods used up to the present time result in bleached fibers, to which the trade is unaccustomed, preferring the raw fiber color. Nearly all of the flax fiber thus far produced by chemical

methods feels harsh and lacks the strength and durability of either dew-retted or water-retted flax.

In some of the fiber districts of Russia the peasants use a combination of shallow pool and dew retting. They commence the work in the fall as soon as the seed can be removed, wetting the straw once by immersion in some shallow pool for a period of one to three weeks, weighting it down by the use of logs or stones. The straw is then removed direct to some grassy meadow and spread in thin swaths for drying and dew retting. (See fig. 5.) The chief reason for the dark color of the great bulk of the raw fiber produced by the Russian peasantry is the carelessness with which they carry out

Fig. 5.—Manner of spreading the flax straw for dew retting.

these processes, as they often allow the straw to remain either too long in the pool or too long on the grass, letting it rot rather than ret.

Another process seen in practice in Russia was a modified pool or pit method. It is there referred to as American, the natives stating that it was introduced by a very bright American. This belief, however, could not be confirmed. Very fine results are obtained by this method. The straw is stacked until May and is then immersed in deep pits or pools encased in heavy planking or logs capable of holding many tons of straw in bundles. (See fig. 6.) The retting processes are continued through the summer months. In an instance seen by the writer the pits were placed upon a hillside in such manner that the water from the spring above was allowed to pass through

a series of pipes from one pit to another; and, as there is an automatic arrangement governing the inflow and outflow of the water, the temperature of the fermenting straw and surrounding water can there be kept at a very regular point. When the straw is first put in and the water is turned on, the temperature rapidly rises, but it is not allowed to go above approximately 110° F.

An outline of this process may be indicated by the following steps: (1) The bundles of straw are placed in the pit and wet up for a period of twenty-six hours; (2) the water is turned off and the mass of straw is allowed to heat for thirty-six to forty-eight hours, care being

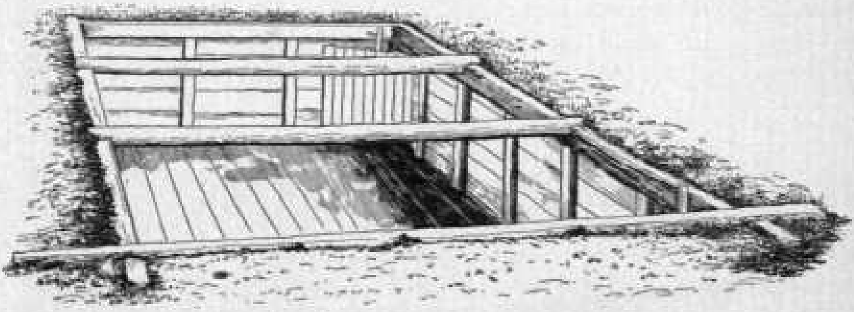

FIG. 6.—Artificial flax-retting pool in use in Russia.

taken that the temperature does not rise above 110° F.; (3) the water is turned on again for sufficient refreshening to keep the temperature down, the straw being allowed to remain from one to three weeks, according to the progress of retting; (4) the straw is next spread out in swaths upon the grass to dry and dew-ret for a period ranging from one to three weeks, according to the conditions observed; (5) after proper drying the straw is placed in bundles and stacked dry.

BREAKING AND SCUTCHING.

After it is retted, the straw should be bright, thoroughly dry, and have a rather sweet odor. At Courtrai, Belgium, the straw, after being retted, is dried and stacked and remains in the stacks until the close of the retting season, when the breaking and scutching operations commence. As the wood, skin, or bark parts are harsh and brittle and the fiber elastic and tough, the straw is broken or crushed in such manner as to cause the wood to drop away from the fiber masses. This process is called breaking. The straw may either be crushed by pounding with mallets or crimped in some sort of breaking machine.

Although the breaking and scutching may be well done by machinery, yet, at best, much hand labor is needed in order to keep the fiber properly bunched, graded, and free from snarls. That

which becomes much snarled must be disposed of as tow. The usual machine break (fig. 7) in Europe consists of pairs of horizontally placed fluted or corrugated rollers, through which the retted straw is passed endwise. There are usually from six to twelve pairs of such rollers, so adjusted that each pair crimps somewhat more closely and fits more tightly than the preceding pair. Flax breaking machines used in America usually consist of five corrugated rollers, arranged so as to give an interrupted or retrograde movement.

The scutching is done by means of flattened paddles. If done by hand, a bunch of broken fiber is held tightly in one hand, while a glancing stroke is made with a thin, smooth paddle, the process being continued until all of the coarse bits of broken wood are removed. In the regular scutching mills the work is done by a set of revolving

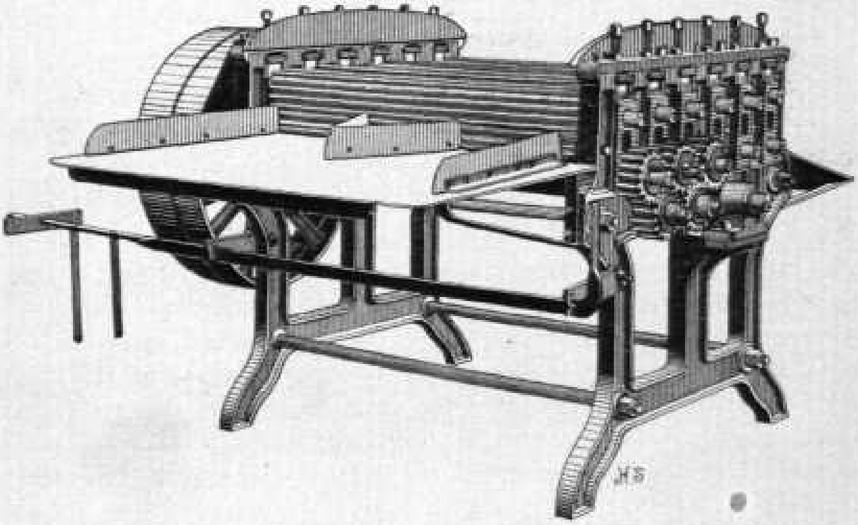

FIG. 7.—Typical flax-fiber breaking machine.

paddles, while the fiber is held in the hand of the operator in such manner that the paddles strike it a glancing blow as it rests over a rounded, smooth-edged board with slanted sides or edges, the ends of the bunch of fiber being reversed from time to time during the process.

In a properly arranged scutching mill there is a series of stalls for the operators, in each of which the scutch wheels revolve upon a power shaft. There are 12 paddles to the wheel, and the wheels revolve at the rate of 150 revolutions per minute. The paddles thus strike regularly upon the fiber at the rate of 1,800 times per minute. Because of this regularity of action the operator is able to judge to a nicety the progress and finish of the work. As it is exceedingly dusty work, ventilation stacks are provided, with hoods covering each wheel, and an air blast carries off all dust and light matter. (See

fig. 8.) In Belgium it is a common practice to divide the scutching process into two or three periods, placing the fiber in cold storage

FIG. 8.—A Belgian scutching mill, showing the position of the operator with reference to the scutching wheels and sorting stalls.

during the rest period between the scutchings. This method of work is said to give flexibility and "life" to the fiber.

SORTING, BALING, AND GRADING.

The scutching process results in cleaning the fiber of all the woody matter, and while this is being accomplished the operator throws the flax into separate piles, according to his judgment of quality. It is then tied into small bundles and finally baled, each bale being supposed to contain fiber of equal quality as to market value. It is baled under pressure into small bundles approximating 200 pounds. The best qualities of fiber are usually encased in covers of coarse gunny sacking, and each bale is marked to indicate its grade or quality before it is allowed to be placed on the market. This is done in the large warerooms by opening the bales sufficiently to draw samples of the fiber.

The writer often saw the process of grading in operation. In the Netherlands the tests applied are such as can only be made by those who have had long association with fiber work. It was observed that in all types of the finest fiber grades the fiber strands were perfectly free from woody or extraneous matter and entanglement. The best types were usually of a pale-gray color, shading slightly to a light golden greenish cast. If too raw or green in color, the fiber may represent an insufficient retting and degumming. If too white, it is found to have lost pliability, life, and perhaps strength. Very dark gray types of fiber, such as that usually sold by the Russian peasantry, represent undue retting and exposure to weather, whereby much strength and pliability are lost before the process of artificial bleaching may bring the fiber back to a usable form.

FLAX DISEASES.

Much effort has been made by the writer to obtain information concerning the chief flax diseases and the relation of each to cropping methods. It has been the aim to learn as much as possible regarding the flax wilt and the various damping-off diseases which have proved to be so seriously destructive to the American seed crop. Careful observations were made at all the European cropping points with a view to ascertaining facts which might aid in combating these troubles. Previous to these European studies the writer had learned that a soil trouble is recognized in practically all flax-producing countries. It manifests itself in a gradual dying of the crop from the time the seed begins to germinate until the crop is quite mature, in the later stages giving the appearance which may well be designated as wilt. As the plants rapidly dry up after dying, they assume a blighted appearance as if struck by fire.

The flax crop gives a fair yield upon new land, but if allowed to follow itself year after year soon ceases to be profitable, for the crop dies away to such an extent that there is not sufficient stand left to pay

for the work. The soil is then said to be "flax-sick" or "exhausted" for flax culture. (See fig. 9.) It has been demonstrated at the North Dakota Agricultural Experiment Station that the trouble is not primarily with the soil, that the soil is not chemically exhausted, but that the trouble is due rather to the presence in the soil of micro-organisms. The chief one of these organisms has been named *Fusarium lini*. The writer has since found that there are several species of Fusarium which act in the same manner, that a species of Colletotrichum is destructive at times, and that various species of Alternaria are able to do much damage to the flax crop under certain weather conditions. Several of these fungi may be acting separately or together and yet give many of the characteristics of the disease which are usually noticed.

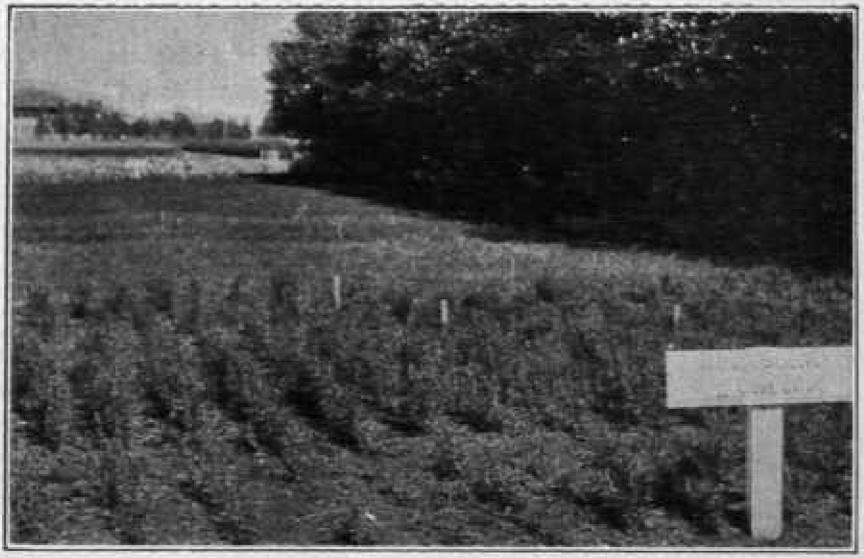

FIG. 9.—"Flax-sick" ground, showing the method of testing various samples of Russian flaxseed to determine their resistance to wilt diseases. Second year's trial. The dying away of the crop is apparent.

These studies demonstrated the fact that these fungous troubles are usually introduced into a new soil by the seed which is sown, and bits of old straw, chaff, and other matter which contain the living organisms are also thus distributed in the soil. It was also proved that by proper treatment of the seed by the formaldehyde method it is possible to prevent the occurrence of the diseases, provided the land is not already infected. It was also shown that marked benefits may arise from proper crop rotation, and the fact was noted that various individuals, varieties, and strains of flax may exhibit a high degree of immunity or resistance to the attacks of these wilt diseases.

The flax wilt fungus was not found to be as destructive in the Netherlands as in America or in Russia. There are various reasons which may be assigned for this, the chief of which rests in the nature of the soil and the extreme care with which the Hollanders grade the seed to evenness of strength and quality. When so doing, they discard all dried particles of straw and shriveled seeds. The writer learned in early experiments that these matters constitute the chief source of soil infection. The careful pulling of all of the straw and its removal to distant retting grounds, it is believed, also tend to dispose of one of the great sources of disease accumulation in the soil. In America great masses of flax stubble are plowed under each year. This decaying mass serves to foster and develop the wilt diseases throughout the entire flax area, so that a given field is often so thoroughly filled with fungi the first year that no flax can thereafter be grown.

The writer's investigations leave no doubt that the present soil troubles are not new manifestations. They are but extensions of diseases which are characteristic of the native flax plants and are perhaps more strongly developed upon cultivated varieties. It is very probable that in proportion as these cultivated varieties are delicate and luxuriant in growth, the diseases have become more destructive. It is also evident that the troubles are widespread, and as the fungi which cause the diseases have the power to live upon decayed matter, as well as powers of parasitism, they may be encountered in any flax-producing region. For this reason, while seed treatment and careful, clean cultivation may tend to prevent rapid soil contamination, it is not likely that it may be possible wholly to escape such troubles by these means. The studies have also demonstrated that there are numerous species of native flax which are not subject to the action of such parasites and certain species which are but slightly open to attack, and that the cultivated varieties used for seed and fiber show marked variation in their ability to resist the attacks of these different fungi. There is therefore much to be hoped for from intelligent selection of varieties and from careful selection, crossbreeding, etc., within the varieties.

VARIETIES OF FIELD FLAX.

Considerable attention has been given by the writer to the question of the existence of fixed varieties within the species known as *Linum usitatissimum*, the common field flax. Most practical growers throughout Europe, and especially in Russia, contend that there are no absolutely fixed varieties. Numerous observations made in the different countries, however, concerning single forms, have convinced the writer that there are several well-marked varieties of cultivated field flax. (See fig. 10.) Among these there are at least two which should

be classed as species, namely, *Linum usitatissimum* L., including all of the small-seeded varieties, and *Linum humile* Mill., including the large-seeded varieties. Of the first-named species, the following varieties may be listed: (1) Common blue-flowered fiber flax; (2) common blue-flowered seed flax; (3) dehiscent-boll seed flax; (4) common white-flowered fiber flax; and (5) white-flowered white-seeded flax.

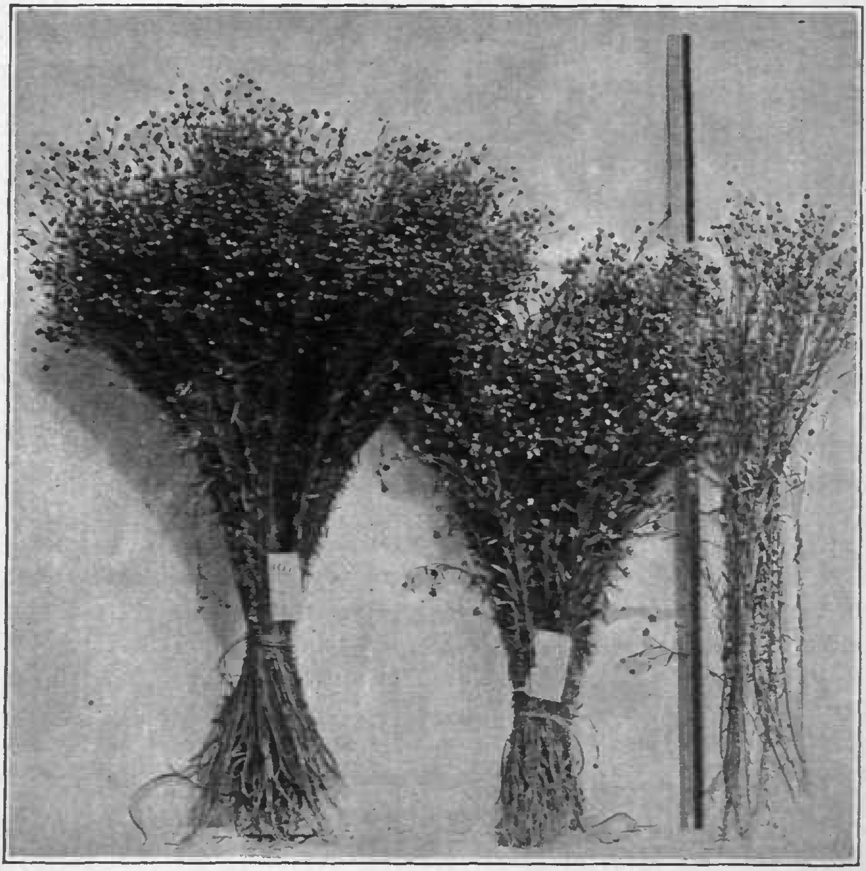

FIG. 10.—Types of North Dakota grown Russian seed flax of three evidently distinct varieties.

Of the big-seeded Sicilian species, *Linum humile*, the following types may be noted: (1) Sicilian big-seeded, blue-flowered seed flax, sometimes grown as a winter variety; (2) big-seeded, white-flowered, white-seeded flax; and (3) Indian seed flax, Egyptian seed flax, and Argentine seed flax. The latter are large-seeded varieties of a character almost midway between the Sicilian big-seeded flax and the common Russian seed flax. Each has some qualities distinguishing it more or less definitely.

There seem to be many intermediate grades or strains between the two species mentioned and within the various varieties named. Because the crop has always been grown without much care as to purity or variety there have been much intermingling and mixing—possibly crossbreeding—and it is a matter worthy of experiment to determine just how far the so-called "running out" of varieties is due to crossbreeding and how much is due to mixing from careless handling of the seed. Studies conducted upon the varieties of these two species of cultivated flax tend to indicate that they are usually close-fertilized. Individual flowers, for example, produce seed freely whether in association with other flowers or not. The structure of the flowers, while possibly allowing cross-fertilization, is such as to indicate that they do not usually cross-fertilize to any great extent. It is the opinion of the writer that practically all cases in which the different varieties are reported as "running out" may be traced to careless seed handling and mixing, whereby the common type characteristic of a particular region soon predominates over the imported strain.

FUTURE OF THE FLAX INDUSTRY IN AMERICA.

Although the oil and fiber branches of the flax industry in America depend upon the demonstration that flax can become a permanent crop in any given locality in the same sense that wheat, corn, or cotton are now permanent elements of agriculture, the writer's observations show that there are regions where, even now, without special knowledge of the existence of disease, the farmers have succeeded, through careful culture and rotation, in saving the crop and keeping it a permanent element of the local agriculture. In Europe the most noted locality in this respect is that immediately surrounding Courtrai, in Belgium. The writer's experiments in North Dakota and his observations in foreign countries teach that there is only one bar to the possibility of the crop becoming a permanent one, viz, the presence of persistent soil-infecting diseases. Now, it has been learned how to avoid infecting new areas, and also how to prevent the spreading of the diseases from infected soil. The most important features consist in each farmer raising, cleaning, and grading his own seed flax and in seed disinfection.

RECOMMENDATIONS TO GROWERS.

Raise your own seed. Grade it to a plump, bright type, removing all particles of chaff and bits of straw, and then treat it before

sowing. Observations in the most noted European flax areas and experiments in North Dakota upon crop rotation tend to show that this feature of sanitary cropping may aid materially in the continuation

FIG. 11.—Four types of flax fiber, and a bundle of North Dakota grown Russian fiber flax from seed sown at the rate of ½ bushel per acre. The latter shows the coarsest form, 47 inches in length. (1) Best quality Belgian fiber; (2) best quality north Russian prepared fiber; (3) hand-broken and scutched fiber prepared from North Dakota grown dew-retted straw; (5) hand-broken and partly scutched fiber from coarse North Dakota grown straw similar to that shown alongside. The fiber in bundle No. 3, while somewhat longer and more tangled, appears in no way inferior to the Russian product, No. 2.

of this crop in a particular soil or locality.[a] Chemical experiments show that flax does not particularly exhaust the plant foods in the soil—at least not more so than many grain crops. Trials of the fiber crop in Oregon, Michigan, Wisconsin, North Dakota, and other States have proved that fine grades of fiber can be grown. Retting and scutching tests conducted at the North Dakota Experiment Station upon North Dakota grown fiber straw show that the fiber is of good form and of splendid strength. (See fig. 11.)

Practice a long-period series of crop rotation, in which are included at least two cultivated crops and two or more years in grass and pasture.

Avoid using poorly composted barnyard manures which contain flax straw.

After using tools, such as plows and harrows, upon wilt-infected land, do not use the same tools upon other land until they have been properly cleaned.

Careful selection, cleaning, grading, and treatment of the seed, together with proper soil cultivation and crop rotation, will make possible the continuation of the linseed industry in America, and with recent developments in manufacture may make possible a flax-fiber industry in this country. If these steps are not soon taken by our farmers the crop is doomed to disappear as one of standard character.

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[a] The method of seed treatment now followed on many North Dakota farms is essentially as follows: Good, bright, plump, yellow flaxseed is selected and cleaned in a fanning mill until only heavy-weight seeds remain, all bits of straw, chaff, dust, and scaly seeds being blown out. The formaldehyde solution is made to the strength of 16 ounces of standard formaldehyde to 40 gallons of water. The cleaned flaxseed is laid upon canvas or a tight floor in quantities of 5 to 10 bushels, and the seed is gradually moistened by the use of a fine spray thrown from a small force pump while it is being rapidly shoveled or raked over. In this manner the flaxseed quickly moistens over its external surface and can be thoroughly dampened without causing it to mat together, the process taking one-half gallon of solution per bushel of dried seed. It is of advantage to cover the pile of seed with canvas or a blanket for a few hours after treatment to keep the exterior of the pile from drying too rapidly. Grain thus treated, when once or twice shoveled over, will readily run through an ordinary drill in two hours after treatment.